Theme 4 : Integrated land and water management

4.1. Livelihood improvement through Resource Conservation (RWC-CIMMYT Collaborative Project)

A. Accelerating the tillage revolution in the Indus-Ganges basin: Fostering adoption of resource conserving technologies to promote economic growth, resource conservation, and food security (USAID)

B. Multi-stakeholder programme to accelerate technology adoption to improve rural livelihoods in the rainfed Eastern Gangetic Plains (IFAD)

(A.K. Sikka, A.R.Khan, UjjwalKumar, Abdul Haris, A.R. Reddy and U.S. Gautam (till.30.07.2006))

The project initiated in May 2004 is continued for third year. Participatory on-farm research on RCTs was undertaken in the five project villages and activities were extended in another 11 villages in 3 districts of Bihar namely Patna, Buxar and Vaishali for upscaling. The following interventions were evaluated:

Zero Till direct seeded rice (ZTDSR) : This practice was evaluated in 40.2 ha area among 65 farmers in *Kharif*, 2006. The average yield of rice under ZTDSR varied between 4.9 - 5.3 t/ha in comparison to 3.2 - 3.8 t/ha in conventional practice. The higher yield is attributed to maintenance of desired plant population, better fertilizer application in the slit and longer crop duration compared to conventional tillage. Net profit of more than Rs. 7000/ha was observed with ZTDSR besides water saving (25 per cent) due to avoidance of puddling and subsequent less irrigation. Resource saving was also possible due to avoidance of nursery and transplanting of rice.

Co-culture of *sesbania* with rice for brown manuring : Brown manuring practice was introduced in 2004 and this was third year when *Sesbania* crop @ 20 kg/ha was broadcasted three days after rice sowing and allowed to grow for 30 days. Co-cultured *Sesbania* crop was dried by spraying 2,4-D ethyle easter. The dried leaves of *Sesbania* fell on the soil and decomposed very fast to supply upto 38 kg/ha N, dry matter, soil organic carbon and other recycled nutrients to the soil. This practice led to reduction of weed population by nearly half without any adverse effect on rice yield. Pest attack was also reduced.

Nitrogen management through LCC in puddled and direct seeded rice : Leaf Colour Chart (LCC) was used to determine the nitrogen status in growing rice in direct seeded/ transplanted /Zero Tillage (ZT) rice. The timings of nitrogen top dressing could easily be determined based on soil N supply and crop demand. This simple tool helped farmers to reduce the excess use of nitrogen fertilizers and led to fertilizer savings of up to 46 kg N /ha.

Experts from Bill & Melinda Gates Foundation, USA visiting the project site.

Effect of various zero tillage methods on yield : The on-farm trials on various zero tillage methods in wheat were conducted at 80 farmers' fields in 54 ha area. Maximum wheat yield of 4.5 t/ha was obtained by use of field king rotary disc drill in control traffic treatment wherein the crop was sown in rice residue. The next higher yielder method was ZT wheat in ZT rice (double zero till) with yield of 3.5 t/ha. ZT equal row and paired row were also better performers over conventional rice -wheat system (2.3 t/ha). In general, there was saving of Rs. 1550 -1700/ha in tillage operations as compared to conventional tillage.

Effect of balanced nutrient management in surface seeded wheat : Surface seeding (SS) is done in low lands where excess soil moisture does not allow tillage operation till end of December. Wheat seed @ 160 kg/ha is normally broadcasted in standing rice crop 10 to 15 days before harvesting. Sometimes sowing of wheat is done immediately before harvest of rice. No basal fertilizer dose is applied. N is applied as top dressing. Therefore, use of P and K was introduced as an intervention to evaluate the affect of balanced fertilizer dose under such situation. This produced 1.05 t/ha higher wheat yield over the conventional surface seeding without P & K giving a net additional benefit of Rs.4500/ha.

Sri A. K. Upadhyay, Secretary, ICAR discussing with farmers and scientists during visit to project site.

Crop diversification by introduction of alternate production system : Wheat crop of the project area was evaluated against other diversified winter crops by introduction of QPM + potato on raised bed, sugarcane + vegetable and maize + vegetable on level lands where there was no risk of water submergence by canal water. Yield of potato sown on raised beds was in the range of 19.75 to 36.20 t/ha compared to 14 - 18 t/ha under farmers' traditional practice. Farmers have benefited from the cultivation of potato, which fetched them good remunerative price. Quality Protein Maize (QPM) seed was sown 20 cm apart on the slope of the bed, 5 cm above the furrow bed. The QPM was harvested early before the heavy attack of the grasshopper. The introduction of QPM along with potato in the month of November (first week) is profitable proposition because apart from potato, farmers got good yield of maize.

An extra early short duration Pigeon Pea (ICPL 88039) was introduced during kharif for diversification and intensification of crop and it gave 0.8 -1.1 t/ha grain yield. Another crop was taken in rabi season after harvest of pigeon pea. Farmers' response was encouraging since they could take wheat after harvest of pigeon pea during the month of December.

Summer mung (cv. Vishal) of 65 days duration was also introduced in 5.3 ha area among seven farmers as para crop before the harvest of wheat to increase the cropping intensity and income besides soil fertility built up. The average yield of mungbean was 0.75 - 0.82 t/ha.

Alternate livelihood support system for landless women, unemployed rural youth and marginal farmers : Early season vegetables in summer are more remunerative but nursery raising due to low temperature in winter is difficult. Therefore, raising vegetable nursery under polyhouse was assessed. By the use of polyhouse, flowering was advanced by about 20 days and fruit setting was advanced by about one month. In a small polyhouse (5m x 25m x 1.6m) costing Rs.3500, one SHG of 11 members grew 3,800 nursery plants; out of which 2500 plants were retained for self use and 1300 seedlings were sold @ Rs.1/plant. The group earned Rs. 7,200 from the sale of vegetables giving a total earning of Rs. 8,500. Three SHGs of unemployed rural youths were formed for raising seedlings in polyhouses.

Landless families have lesser chance of income generation during lean period. Oyster mushroom production was introduced for landless families. A group of landless farm women in village Azadnagar formed SHG named *Mahila Utthan Samiti*. The group is intensively involved in mushroom production. The SHG prepared 350 packets of mushroom cultivation. The minimum yield from each packet was one kg and it was sold @ Rs. 50/Kg. The cost of production is only Rs. 08 per packet yielding a net profit of Rs. 42/kg.

During summer Milky white mushroom was grown in 134 packets by nine landless women. Each packet produces 1-1.5 kg and is being sold in the market @ Rs. 80-100/kg.



Experts from IRRI and Bill & Melinda Gates Foundation, USA along with ICAR-RCER Director visiting the Landless Women SHGs of Mushroom cultivation

Socio economic activities : A revisit survey of 80 farm households was done and changes over the last three years were recorded. Thirty eight per cent respondents reported increase of physical assets. Thirty two per cent respondents reported improvement in their livelihoods. About 26.5 per cent respondents reported improvement of financial status whereas 48.2 per cent respondents reported no change in their financial status. Around 90 per cent respondents reported decrease in production cost of wheat as well as rice over the last three years as a result of improved practices and technical know how. About 16.8 per cent and 20.5 per cent respondents reported increase in wheat and rice yield, respectively. Trainings organized on different topics of alternate livelihood and second generation of resource conservation technologies improved the capacity of stakeholders.

4.2 Integrated management of rain, canal and groundwater including on-farm water management

4.2.1 Comparative performance of system of rice intensification (SRI) under different plant geometry and water regimes with conventional rice management

(S.K. Singh and R.K. Batta)

The performance of SRI under different plant geometries and water regimes was evaluated for the second year at Sabajpura farm in Patna, during Kharif 2006. The experiment was laid out in a randomized complete block design with ten treatments replicated thrice in 20 m X 2 m plots. The treatments and various growth stages of SRI are as shown in Fig. 20.

Fig. 20. Various treatments and growth stages of SRI

Plant growth, yield and yield attributes differed significantly under SRI (Table 10). Higher grain and straw yields of 7.52 and 10.28 t/ha, respectively were recorded under 25 x 25 cm spacing with 6 cm irrigation applied 3 days after disappearance of ponded water (T_2) as compared to lowest yield recorded under staggered planting with 6 cm irrigation applied 5 days after disappearance of ponded water (T_{10}). Growth and growth attributes followed similar trend.

Table 10 : Growth, yield attributes and grain yield of rice under SRI and conventional transplanting

Treat ments	LAI at booting	Tillers/ hill (Nos)	Panicles / hill (Nos)	Panicle length (cm)	1000 grain weight(g)	Ripened grains (percent)	Grains / panicle (Nos)	Straw yield (t/ha)	Grain yield (t/ha)
T_1	2.90	26.50	17.76	17.90	24.00	83.84	86.40	8.63	6.47
T_2	3.88	29.10	20.58	19.80	29.00	91.51	97.00	10.28	7.52
T_3	3.78	28.54	20.38	19.60	28.00	90.58	94.17	10.20	7.45
T_4	3.70	28.15	20.19	19.30	27.00	89.70	92.23	9.33	7.20
T_5	3.68	28.40	19.61	19.40	26.00	88.06	90.30	9.10	7.00
T_6	3.39	25.90	17.58	17.47	23.00	80.61	84.13	7.75	5.90
T_7	2.70	28.15	20.19	18.25	27.00	90.44	93.20	9.50	7.30
T_8	3.68	26.21	20.19	18.60	23.00	83.00	85.10	8.20	6.32
T_9	2.70	10.97	6.00	17.00	22.00	80.20	79.60	6.37	4.90
T_{10}	1.94	9.70	5.82	15.50	21.00	79.12	76.33	5.62	4.67
CD (5 Per Cent)	0.19	2.39	2.45	1.43	2.32	3.03	3.50	5.68	2.27

4.2.2 Alternate Land Use Systems (Agri-silvi-pastoral) for rainfed areas of Bihar.

(S.K.Singh)

An agri-silvi-pastoral field trial was conducted in silty clay loam soils during 2004-2006 at WALMI farm of ICAR-RCER, Patna. Seven treatments viz., T_1- Subabul (*Leucaena leucocephala)* 2 rows at 3m x 3 m, T_2-Gumhar (*Gmelina arborea*) 1 row at 6mx6m, T_3-Safed Siris (*Albigia procera*) 1 row at 6m x 6m, T_4- Subabul + companion crop, T_5-Gumhar + Companion crop, T_6-Safed Siris + Companion crop and T_7- Sole crop were maintained with 3 replications under Randomized Block Design. Companion crops included one perennial grass viz., guinea grass (*Panicum maximum*) planted at 1 m X 0.5 m spacing. During rainy and summer seasons - Cowpea variety Bundel 1 was grown. During winter season, field pea variety Aparna was sown as intercrop in the interspaces of the guinea grass. The treatments were maintained continuously by reseeding/planting of desirable trees, grasses and legumes in integrated manner and their utilization under cut and carry system. Height of the standing tree as measured from ground level to the crown point was considered as an index of fertility. The basal diameter and diameter at breast height of trees at 24 months were recorded (Table 11).

Table 11 : Biometric observations of trees at 24 months.

Treatments	Tree Height (m)	Basal diameter (cm)	Diameter at breast height (cm)
Subabul	4.22	21.5	11.2
Subabul + companion crop	4.00	18.3	9.8
Gumhar	3.10	24.5	8.5
Gumhar + Companion crop	2.15	15.2	4.9
Safed Siris	3.95	25.2	10.1
Safed Siris + Companion crop	2.35	16.7	6.3

Subabul attained maximum height (4.22 m) followed by Safed Siris (3.95 m). Highest basal diameter was recorded by Safed Siris (25.2 cm) followed by Gumhar (24.5 cm) and was lowest in Subabul (21.5 cm). The diameter at breast height was maximum in Subabul (11.2 cm) followed by Safed Siris (10.1 cm) with lowest in Gumhar (8.5 cm).

Guinea grass along with companion crop

Tree along with companion crops

The results indicated that subabul when intercropped with guinea grass + cowpea/field pea/cowpea during kharif, rabi and summer respectively yielded maximum with a fodder and fuel wood yield of 44 and 4.8 t/ha/year respectively and 2 t/ha of pod yield of green field pea for human consumption. However, sole subabul gave 3 and 6 t/ha/year of fodder and fuel wood yield, respectively (Table 12).

Table 12 : Fodder and fuel wood yields under different treatments of agri-silvi-pastoral system

Treatments	Fresh fodder (t/ha)	Fuel wood (t/ha)	Green pods (t/ha)
Subabul	3.0	6.0	–
Gumhar	2.0	4.3	–
Safed Siris	2.7	5.2	–
Subabul + Companion crop	44.0	4.8	2.0
Gumhar + Companion crop	37.1	2.4	1.80
Safed Siris + Companion crop	40.2	3.9	1.90
Sole crop	35.0	–	1.98
CD (P=0.05 per cent)	6.4	0.65	3.0

The soil fertility changes indicate that organic carbon content of soil was higher in subabul pure tree than other trees (Table 13). This may be attributed to addition of litterfall, root density and other organic materials contributed by subabul. The highest increase in available nitrogen in soil (14 kg/ha) was recorded with subabul + companion crop and this may be attributed to the direct addition of nitrogen through residues of companion crop and subabul. The favourable soil conditions due to N addition of subabul might have helped in the mineralization of soil N leading to build up of higher available N. Higher addition of organic matter through subabul also helped in releasing the higher amounts of phosphorus from the soil. Available potash was maximum in case of Safed Siris followed by Gumhar and Subabul since nutrients addition in the soil through litter fall largely depend on the tree species, quantity and quality of litter and the ease with which it is decomposed in the soil.

Table 13 : Changes in soil fertility due to introduction of agri-silvi-pastoral system

Treatments	pH 1: 2 solution		Organic carbon (per cent)		Available Nitrogen (kg/ha)		Available phosphorus (kg/ha)		Available potash (kg/ha)	
	Initial	After 2 years	Initial	After 2 years	Initial	After 2 years	Initial	After 2 years	Initial	After 2 years
Subabul	7.7	7.5	0.72	0.90	280	287	35	40	400	411
Gumhar	8.4	8.4	0.65	0.72	275	288	32	37	350	362
Safed Siris	7.9	7.8	0.66	0.74	280	290	34	38	380	402
Subabul + Companion crop	7.6	7.6	0.73	0.80	281	295	34	38	410	422
Gumhar + Companion crop	8.4	8.4	0.66	0.72	282	290	38	40	405	415
Safed Siris + Companion crop	7.9	7.8	0.67	0.75	283	292	36	39	403	411
Sole crop	7.8	7.8	0.65	0.72	284	288	39	41	400	405

4.3 Assessment of water productivity and multiple uses of water

4.3.1 Strategies for enhancing land and water productivity through multiple uses of water

(A.K. Sikka, P.R. Bhatnagar, A. Haris, D.K. Kaushal, L.K. Prasad, Ujjwal Kumar, A.R. Reddy, A. Dey, R.V. Singh, Bikash Das and P. Dey)

Enhancement of water productivity in canal seepage induced waterlogged lands and plateau regions was investigated with various interventions such as fish trenches cum raised beds for fish-horticulture integration, secondary reservoir for multiple uses, rice-fish culture, rainwater harvesting and its multiple uses, and small water harvesting dobas (Jalkundas) for establishment of horticulture on uplands.

Secondary reservoir

Productive utilization of the secondary reservoir SR-M (i.e. with water routing) and SR-C (i.e. control) to intercept seepage from Patna Main Canal was assessed. Due to sub-normal rainfall, the canal was operated only for 29 days during the season. A total of 2283 m^3 of water was supplemented from ground water during expected canal off period to maintain water level between 1.0 to 1.5 m throughout the season.

Monitoring of water quality in the secondary reservoir during 2005-06 indicated nutrient accumulation in the SR-C with nitrate, phosphorous and potassium concentration on an average of 2.4, 0.13 and 6.26 mg/l as compared to 0.9, 0.10 and 5.69 mg/l in SR-M, respectively. Dissolved Oxygen was relatively higher in SR-M (7.54 mg/l) than SR-C (7.12 mg/l). The pH of the pond remained in the range of 7.1 to 8.9 for both the reservoirs and it increased during summer period and remained nearly neutral during winters.

Polycultured fish fry stocking consisting of rohu (*Labeo rohita*), silver carp (*Hypophthalmichtys molitrix*), catla (*Catla catla*), common carp (*Cyprinus carpio*), grass carp (*Ctenopharyngodon idella*) and mrigal (*Cirrhinus mrigala*) in the ratio of 2.5:2.5:1:2:1:1 with stocking rate of 15000/ha was done in August 2005 in both the reservoirs. In June 2006, a fish harvest of 470 kg (4.75 t/ha) and 300 kg (3.03 t/ha) was obtained, respectively from SR-M and SR-C. Further fish fry stocking was done in August 2006. Observations on growth of fish revealed that after 150 days of rearing, common carp, silver, catla, grass carp and rohu, attained weight of 240, 220, 180, 153, and 93 g in SR-M and 104, 300, 178, 72, and 130 g respectively in reservoir SR-C. Fish growth especially of grass carp and silver carp was better during winters (Nov-Dec) with improvement in dissolved oxygen (6-10 mg/l). Fish weight increased with increased phosphate concentration and there was little decrease in phosphate content at later period. The phosphate and oxygen contents might have enhanced availability of bio-plankton, which helped superior growth of different fish species.

Khaki Campbell ducks (15 female and 9 male for each reservoir) were introduced in February 2005. Upto December 2006, the ducks attained an average body weight of 1441 g and 4170 eggs (average weight of 65.75 ± 1.35 g) were laid since July 2005. A total of 1267 kg fresh droppings were laid in each reservoir in one year. The mortality rate of ducks was recorded as 7.84 per cent.

Banana, guava and lemon along with variety of vegetables were grown in two tier system on the bunds. The production of these fruits was 253 bunch (3.76 t), 151 kg and 1540 no., respectively from SR-M and 91 bunches (1.37 t), 138 kg and 38 no. from the SR-C.

Fish trenches-cum-raised bed

For productive use of the waterlogged lands having moderate depth of water stagnation (0.3-1.0m), the concept of fish trenches was assessed with two types of layout: 1) meandering type simulating river flow (Tr-R), and 2) island type simulating pond and island type conditions (Tr-P). As the canal was not operated in its normal periods, about 8300 m^3 and 7800 m^3 of water was supplemented from the tubewell to TR-R and Tr-P, respectively. For the period when canal flow was not expected, 4878 m^3 and 4630 m^3 of water was required to be supplemented.

Polycultured fish fry was stocked similar to secondary reservoir in August 2005. In June 2006, a fish harvest of 87 kg (1.99 t/ha) and 90.5 kg (1.94 t/ha) was realized; respectively from Tr-R and Tr-P having water spread area of 438 and 466 m^2, respectively. In August 2006, the fish fry were again stocked. After rearing of fish for 150 days, observations on growth of fish revealed that silver carp attained a weight of 168 g in lentic conditions and 149 g in riverine conditions. Catla indicated better growth with an average weight of 150 g in riverine condition. Common carp ranked third in terms of gaining weight. The growth of fish in trenches was again slow as compared to their growth in service reservoir, could be due to availability of more area and depth of water. The water quality of both the system was more or less similar with average values of dissolved oxygen around 7.0 mg/l, pH of 7.8, Sacci disc transparency of 32 cm, nitrate of 0.65-1.15 mg/l, phosphorous 0.16 mg/l, and potassium of 7.6-8.6 mg/l.

Banana and vegetables have been grown on the raised bunds, which comprised of about 45.6 per cent of total area in the intervention (1984 m^2). Up to December 2006, 223 bunches of banana (44.04 t) were produced along with vegetables worth Rs.15,427.

Rice-fish culture

Rice- fish trial has been conducted for the third year as an intervention for enhancing the productivity of shallow waterlogged lands. Five treatments involving two stocking density (@ 20,000 and 30,000 fingerlings per ha of refuge area) and two stages of fish fingerlings (a month old fry and stunted yearlings) were assessed with control (no fish). In the experimental field, water remained above ground surface for an average of 73 days, out of which 26, and 6 days had water depth more than 10 cm and 20 cm, respectively above the ground, which created congenial water depth for fish to move in the zrice field. On an average, 332 m^3 of water was required to maintain the water level in the rice field when water availability from other sources was less. However, with normal canal operation, this is expected to be reduced to 65 m^3, amounting to a cost of Rs 54 for a plot of 50 x 30 m^2, or Rs 221 for one hectare.

The dissolved oxygen and pH in the water was congenial for fish growth and varied between 5.8 to 11.4 mg/l and 7.21 to 8.33, respectively. The average concentration of nitrate, phosphorous and potassium was 1.21, 0.20 and 7.37 mg/l, respectively. The Sacci transparency was 24 ± 10 cm.

Rice (cv. MTU 7029) was grown in five plots of 50 x 30 m with 15 x 10 m fish refuge dug out in centre of the plots. Each plot was divided into four sub-plots for fish treatments. Fish fries of rohu, catla, silver carp, common carp & mrigal in the ratio of 1.5:1.5: 1:3:3 were stocked in the first week of August 2006 as per treatments. After rearing the fish for 120 days, the partial harvesting resulted in an average yield of 1.36 t/ha. On an average the biomass yield and grain yield of paddy was 16.08 and 4.74 t/ha. There was no significant difference among the treatments.

Mean values of fish and paddy yield obtained during three years of the study i.e. in 2004, 2005 and 2006, are given in Table 14. Although, there was no effect on paddy yield due to stocking of fish in the paddy fields, but the income was found to enhance by 12-18 per cent due to fish.

Table 14 : Paddy and fish production in rice-fish trial, average of three years (2004-2006) of experimentation

Treatment	Paddy (Bio) (t/ha)	Paddy (Grain) (t/ha)	Fish (t/ha-refuge)	Income (Rs/ha)		
				Rice-fish	Rice alone	per cent Increase over control
Y-20000	15.02	5.49	1.60	32693	27454	14.8
F-20000	14.42	5.84	1.10	31755	29187	11.5
Y-30000	14.85	5.86	1.44	33561	29284	17.9
F-30000	14.57	5.52	1.14	30523	27583	7.2
Control	14.32	5.69		28467	28467	
Mean	**14.63**	**5.68**	**1.32**		**28395**	

Economics of multiple uses of water

The economics of different multiple water use systems was worked out and compared with the rice-wheat cropping system, which is prevailing in most part of the eastern Gangetic plains (Fig.21). With incorporation of fish in the rice fields, 6 per cent increase in income can be obtained, while converting the field into fish trenches and growing horticulture on raised bed could enhance the income by 189 per cent. Fish culture in secondary reservoir was the best alternative with 235 per cent more income with fish alone, which could increase up to 374 per cent with fruits and vegetables grown on bunds.

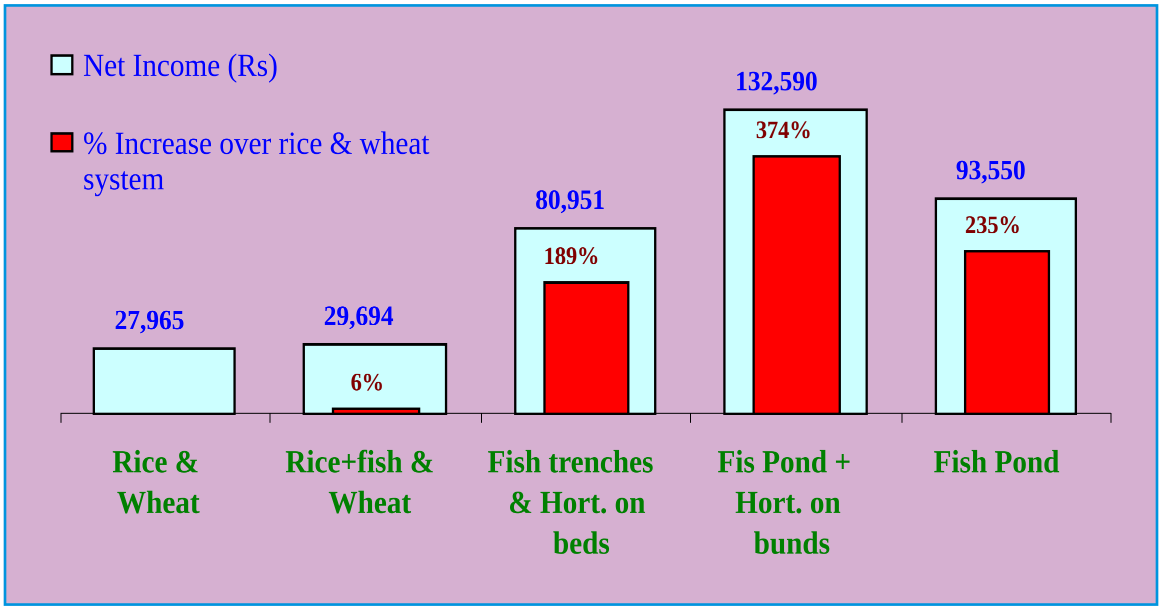

Fig. 21. Economics of different multiple water use systems.

Multiple uses of harvested rainwater

A rainwater-harvesting reservoir has been constructed on the mid-land of the plateau region and lined by LDPE (low density polyethylene) film at the HARP, Ranchi. The outlet of the reservoir was connected to water conveyance pipe such that irrigation may be provided gravitationally in the command area. Multi-tier horticulture system comprising of litchi as main crop, guava as filler crop was planted in September 2005 in the command area with vegetables (including pea, french bean, cucumber and tomato) on about 1000 m^2 only due to constraint of water availability. Gravity fed drip irrigation system was laid out in the command to irrigate the fruit and vegetable plants which had emission uniformity of 89 per cent with pressure head varying between 1.0 to 2.5m for emitters laid on sloping land. A total of Rs 13,722 was earned from vegetable production in the command. With the supplemental irrigation from the harvested rainwater, rice and cowpea has been sown in an area of 1210 and 456 m^2. The rice harvest was 223 kg (1.84 t/ha). On bunds, bottle gourd, pointed gourd, and maize cobs were grown which gave an income of about Rs 2216. Up to June 2006, the fish harvest in the pond was 32.75 kg. In all, the total income from all the sources was Rs 18,690 in the first year excluding the cost of cowpea which was yet to be harvested.

4.3.2 Water harvesting and better cropping systems for the benefit of small farmers in watersheds of the east India plateau (ACIAR funded)

(S. Kumar, P.R. Bhatnagar and P.Dey)

The Australian Centre for International Agricultural Research (ACIAR) funded project was initiated on 1st April 2006 in collaboration with University of Western Sydney, Australian National University, and Professional Assistance for Development Action (PRADAN, a NGO in India). Two watersheds namely Pogro Watershed (WS-1) and Amagara Watershed (WS-2) were selected in Purulia district of West Bengal, which are dominated by resource poor tribal habitants. WS-1 has poor resource base and considered as untreated watershed, while some water harvesting structures along with vegetable production were already developed by PRADAN in WS-2 and it is considered as partially treated hydrologically. Hydrological measurements have been initiated in Pogro Watershed. Participatory assessment of prevailing agricultural system and need of water during different periods was assessed after interaction with the farmers in both the watersheds. Soil and landscape assessment in Pogro watershed focused on: a) soil descriptions and classifications (12 soil pits completed), representing the major landscape units; b) surface soil sampling and analysis for fertility assessment within each of the main landscape units. PRADAN have produced a 'resource map' of the Pogro watershed. Because of the interest in fertilisers, much of the farmer-initiated activities ended up as 'on-farm research'. Simple crop monitoring was integrated with fertiliser treatments on several new crop options. The resultant experiments explored new crop options for uplands and crop responses to N, P and K as appropriate, as well as broader soil fertility assessment and crop response. All experiments are replicated in a randomised complete block design. Ninety five farmers took up interventions.

Small water harvesting structures created in Amagara watershed Purulia district.

Resource map of Pogro Watershed Purulia district

4.4 Modern irrigation methods including small holder irrigation

4.4.1 Low cost pressurized irrigation system

(Atul Kumar Singh, A. Rahman, A. Upadhyaya and A. K. Sikka)

Three low cost low pressure sprinkling devices namely LEWA, developed by ICAR-RCER, Patna; Mini Wobbler a product of M/s Senniger, USA and one Single nozzle impact sprinkler, a product of an Indian company were identified and tested for their performance.

LEWA device

The LEWA device was tested for (i) radial water distribution vs. operating pressures (0.4-0.6kg/cm^2), (ii) pressure discharge relationship and (iii) effect of pressure on radial throw.

The results (Fig. 22) indicate that the water distribution peak shifts towards outer periphery with increase in operating pressure. Radial throw also increases with increase in operating pressure. Significant increase in radial throw could be observed when operating pressure was increased from 0.2 to 0.5 kg/cm^2 and was more or less constant when operating pressure increases beyond 0.5 kg/cm^2. This indicates that the optimum pressure for LEWA is in the range of 0.4–0.6 Kg/cm^2. Christiansen Uniformity (CU) values estimated for 0.4, 0.5 and 0.6 kg/cm^2 operating pressures ranged between 55 per cent to 70 per cent when row to row and nozzle to nozzle spacing was at 6 m.

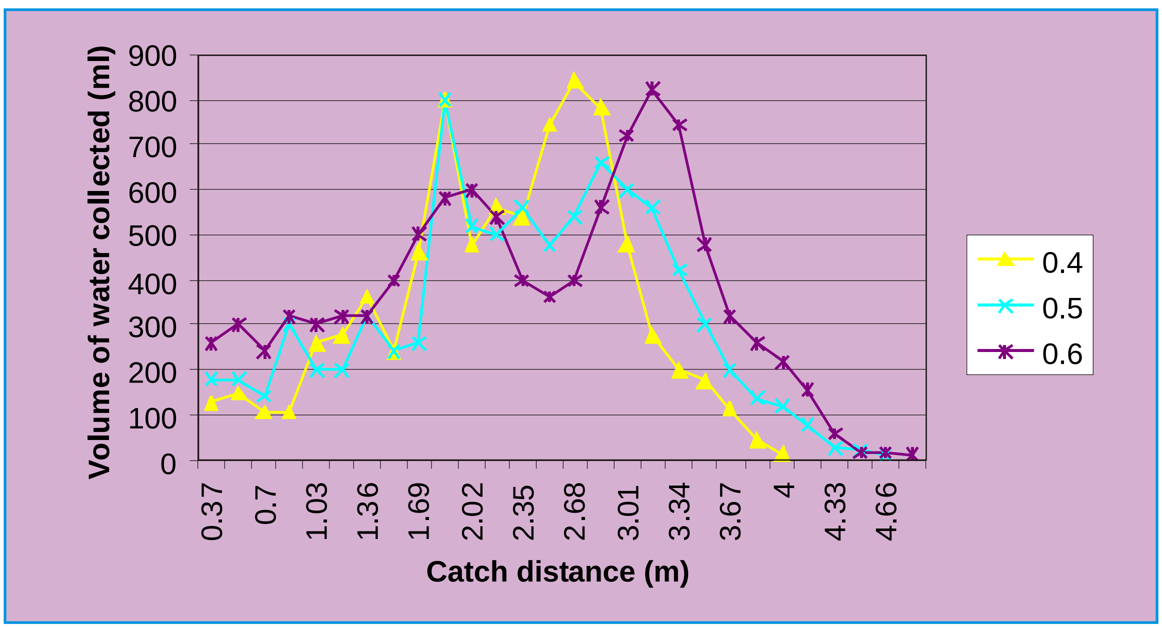

Fig. 22. Effect of operating pressure on radial water distribution of LEWA

Mini Wobbler

Mini Wobbler was also tested for radial water distribution pattern. The radial water distribution of Wobbler at different operating pressure is shown in Fig. 23.

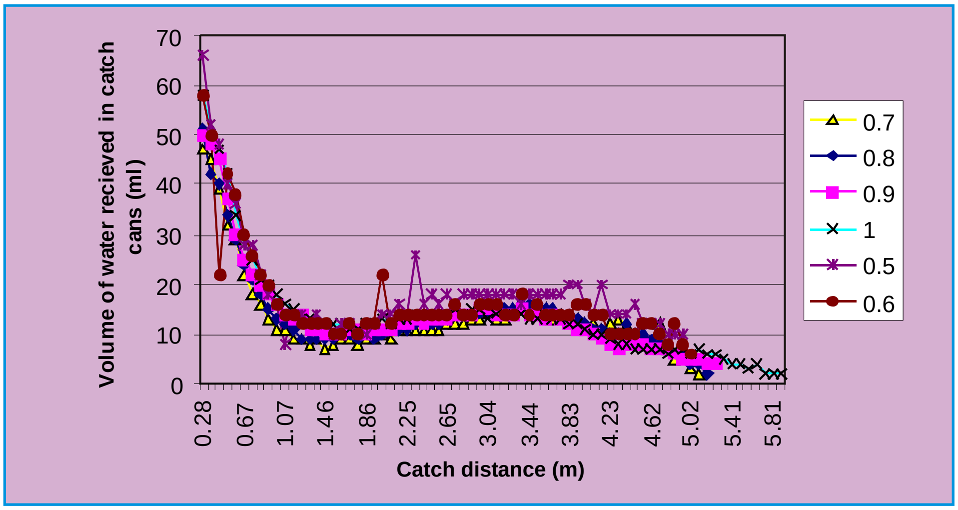

Fig. 23. Effect of operating pressure on radial water distribution of Wobbler

The figure depicts that the volume of water received near the riser is higher than towards its periphery unlike LEWA device. Secondly, it is also observed that radial pattern of distribution is more or less similar when operating pressure varies between 0.6 - 1.0 kg/cm^2. The head-discharge relationship indicates that when operating pressure varies from 0.5 - 1.0 kg/cm^2 at a riser height of 1.0 m, the discharge varies between 0.05 - 0.07 lps. There is a gradual increase in throw diameter as the operating pressure varies from 0.5 - 0.8 kg/cm^2. However, when operating pressure was increased beyond 0.8 kg/cm^2, an abrupt increase in throw diameter was observed.

Single nozzle sprinkler

In case of single nozzle sprinkler (Fig. 24) it is observed that higher volume of water is received near the riser, which decreases continuously towards periphery. This indicates that operating pressure at a nozzle head of 1.5 kg/cm^2 or above is optimum for this type of sprinkler.

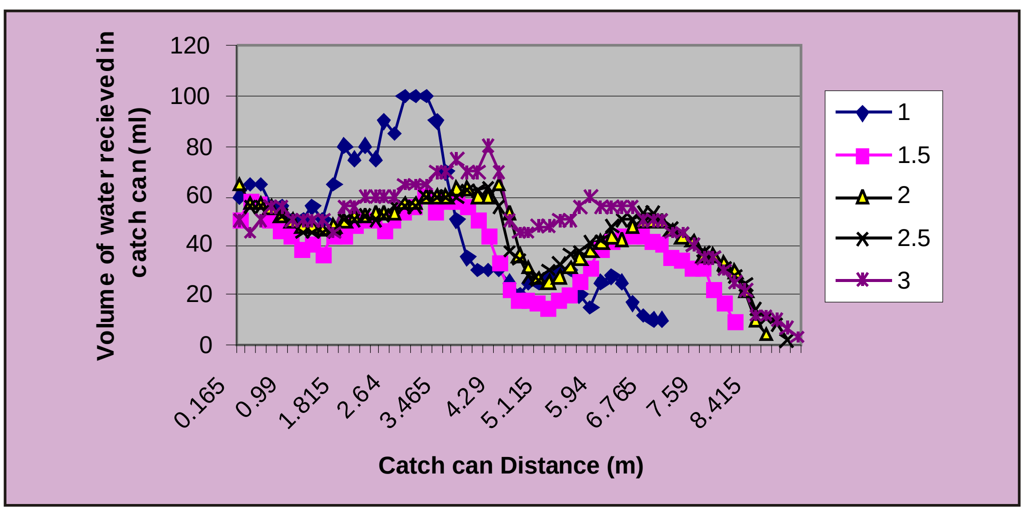

Fig. 24. Effect of operating pressure on radial water distribution pattern of single nozzle impact sprinkler

The relationship between operating pressure and discharge indicates that discharge of the sprinkler varied from 0.11- 0.2 lps when operating pressure was increased from 1.0- 3.0 Kg/cm^2 respectively. Also it was observed that increase in radial throw diameter was higher when operating pressure varied from 1.0 -1.5 kg/cm^2.

A block test was undertaken to estimate the uniformity at 6m x 6m and 12m x 12 m of spacing under 1.0, 1.5 and 2.0 kg/cm^2 operating pressures. It is seen that at 6 x 6 m spacing the uniformity (CU values) is over 75 per cent. The CU values estimated were 78.5, 87.6 and 90.6 per cent for 1.0, 1.5 and 1.5 kg/cm^2 operating pressures. This indicates that if sprinkler is operated at 6 x 6 m spacing it can be operated within 1.0 - 1.5 kg/cm^2 pressure but once the spacing is increased beyond 6 x 6 m the operating pressure should also be increased.

4.4.2 Development of decision support system for design and layout of pressurized irrigation system for different crops

(Manibhushan, A.Rahman, A.Upadhyaya, A.K.Singh and R.K.Batta)

Review of literature on available Decision Support System for Pressurized Irrigation System was done. DRIPD DSS is drip irrigation design system containing an EXCEL spread sheet based decision support tool for water balance in the canal command and various options of water management. A user friendly software Investment Decision Model for Drip Irrigation System (IDEMOIS) gives the threshold economic value of investment cost of drip irrigation system for a given set of parameters for different cropping system. Irrigation water management is very difficult in long canal systems with conventional methods. It is aimed to first develop an Excel based Decision Support System (DSS) for the design and selection of suitable PIS. It will then be transformed into user interactive Graphical User Interface in Visual Basic to make it easy to use. Finally this DSS will be tested and validated in the farmers' fields.

4.5 Climate Change

4.5.1 Impact, adaptation, vulnerability of Indian agriculture to Climate Change

(*A K Sikka, A Islam, B Saha, A Upadhyaya, Abdul Haris A. and A R Reddy*)

(A) Hydrological modeling to assess impact of Climate Change on water resources in the Brahmani basin

The impact of climate change on the hydrology and water availability in the Brahmani basin, which is spread over three states of Orissa, Jharkhand, and Chattisgarh, has been studied using USGS (United States Geological Survey) MMS/PRMS (Modular Modeling Systems/Precipitation-Runoff Modeling Systems) model. Different scenarios considered for modeling climate change impacts on water resources are: hypothetical scenarios (temperature +4 °C and precipitation ±10 per cent with respect to base value (year 1982), PRECIS (**P**roviding. **R**egional **C**limates for **I**mpacts **S**tudies) RCM, and HadCM3 generated scenarios.

The calibration of the model for four different gauging stations (Tilga, Jaraikela, Gomlai and Jenapur) showed a good agreement between monthly observed and simulated streamflow with coefficient of determination (r^2) ranging from 0.91 to 0.98 and modeling efficiency (Nash-Sutcliffe coefficient) ranging from 0.89 to 0.96. During validation phase also model performed quite satisfactorily with coefficient of determination ranging from 0.84 to 0.99 and modeling efficiency ranging from 0.80 to 0.98. Sensitivity analysis conducted using the calibrated model under different hypothetical scenarios indicated 4.8 per cent decrease in annual streamflow with 4°C increase in temperature and no change in rainfall; and 22.5 per cent decrease in annual streamflow with 10 per cent decrease in precipitation and no change in temperature. Simulation results using PRECIS RCM scenario for the year 2020 and 2050 showed 25 and 31 per cent increase in annual streamflow at Jenapur, respectively, over the base year (1980) with maximum increase recorded during the month of November and December (Fig. 25). During the months of Feb to June, there is decrease in mean monthly streamflow in 2020 as well as 2050. Similar results were also obtained using HadCM3 generated scenarios, predicting an increase in annual streamflow by 43, 30 and 64 percent during 2020, 2050, and 2080 respectively.

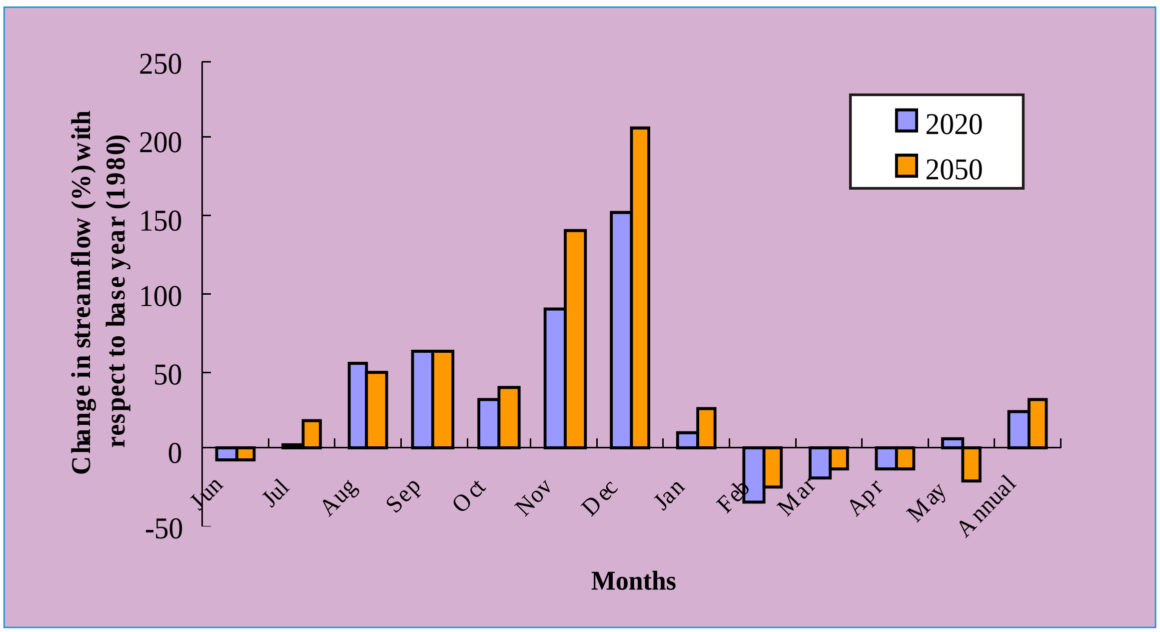

Fig. 25. Change in streamflow predicted at Jenapur using PRECIS RCM scenario

(B) Impact of climate change on ET

In order to study the impact of climate change on actual and potential evapotranspiration at a relatively micro-scale during Kharif and Rabi season, Derjang Irrigation Project site within Brahmani basin (Latitude 20° 50” Longitude 85° 02”) located in District Angul, in Orissa was selected. The GCA and CCA of the Irrigation Project are 11,780 and 7,893 ha, respectively. Rice is predominant crop of the area, besides other crops like groundnut, pulses, sugarcane, sunflower and til (Sesamum) are cultivated in few patches. Four scenarios in 'what if' mode selected are hypothetical scenarios of temperature changes alone by ± 1°C to ± 4°C from the base year data 2000, temperature increase by 1°C to 3°C with rainfall decrease by 10 per cent, and temperature increase by 1°C to 3°C with rainfall increase by 10 per cent. The study was carried out employing Soil-Water-Atmosphere-Plant (SWAP) interaction model with the available soil, water, crop and climate data collected from the project site. Variation in actual ET due to increase or decrease in temperature in the range of 1°C to 4°C is presented in Fig. 26.

Results revealed that during rabi season AET was found to increase from 2.25 per cent to 9.71 per cent when temperature was increased by 1°C to 4°C whereas it was found to decrease from 2.43 per cent to 8.85 per cent when temperature was reduced by 1°C to 4°C. During kharif season AET was found to increase from 2.84 per cent to 11.04 per cent when temperature was increased by 1°C to 4°C, whereas it was found to decrease from 2.39 per cent to 10.09 per cent, when temperature was decreased by 1°C to 4°C.

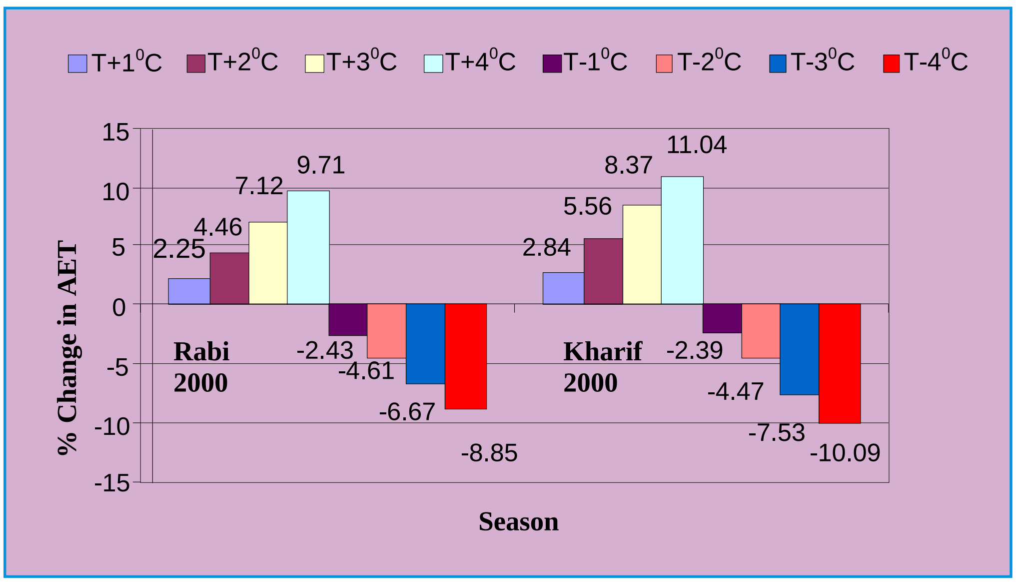

Fig. 26. Per cent variation in AET due to increase in temperature

Variation in AET under the scenario of increase in temperature by 1^{0}C to 3^{0}C along with decrease or increase in rainfall by 10 per cent is presented in Fig 27. Results revealed that during Kharif season AET was found to increase from 5.37 per cent to 13.85 per cent when temperature was increased by 1^{0}C to 3^{0}C with decrease in rainfall by 10 per cent, whereas it was found to increase from 3.77 per cent to 11.94 per cent when temperature and rainfall were increased by 1^{0}C to 3^{0}C and 10 per cent, respectively. During rabi season AET was observed to increase from 3.11 per cent to 9.60 per cent when temperature was increased from 1^{0}C to 3^{0}C and rainfall was decreased by 10 per cent, whereas it was found to increase from 3.07 per cent to 9.45 per cent when temperature and rainfall were increased by 1^{0}C to 3^{0}C and 10 per cent, respectively. The results indicate that the scenario of increase in temperature and decrease in rainfall are more vulnerable and will have adverse impact on irrigation water demand.

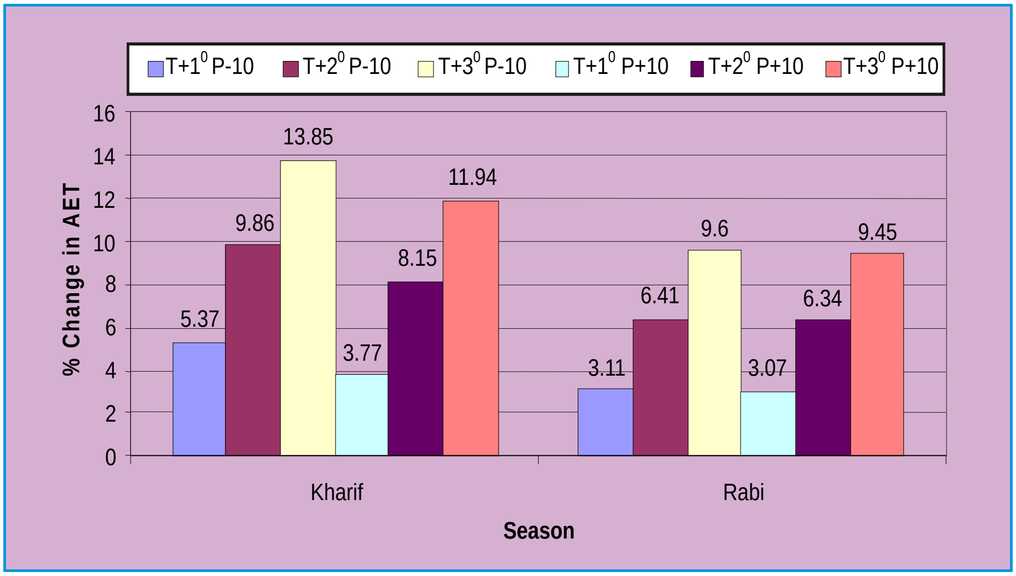

Fig 27. Per cent variation in AET due to increase in temperature and increase or decrease in rainfall

Data on crops grown, inputs used, yield and prices of different farm products produced in the command were collected from farmers by conducting focused group discussions and personal interviews. Crop preferences of the farmers in the situations of water deficit as well as excess were also recorded. Future crop scenarios were worked out based on the preferences of the farmers and expected water scenario in order to understand adaptability. Quantity and value of crop production and input requirements were worked out and compared based on the collected data. Rice is grown in 85.1 percent area of the gross command. Pulses are grown in 575 ha area followed by vegetables (378 ha). In case of increased water availability scenarios, farmers' preference was to increase rabi rice area and to shift rice area to pulses in case of decreased water availability.

Input requirements and yields of different crops in the command area were worked out based on different scenarios. At present the cost of the inputs used was worked out to be Rs. 1424.4 lakh and the value of the production was Rs. 2052.3 lakh. Value of the production was found to increase to Rs. 2093.6 lakh for scenario of 10 per cent increase in rainfall. Similarly value of inputs also increased to Rs. 1461.5 lakh. However, no decrease in the value of production was found for the scenario of 10 per cent decrease in rainfall. This was mainly due to the shift in the crop area from rice to pulses as it needs less input compared to rice. In this hypothetical case, value of inputs used decreased to Rs. 1404.1 lakhs and value of out put increased by Rs. 3.47 lakhs.

This hypothetical analysis indicates that by changing crops alone in the event of climate change, economic vulnerability could be reduced. This suggests that option of various simple crop, land and water management strategies/interventions may be looked into for adaptation to climate change.

Challenge Program on Water and Food

Indo-Gangetic Basin-Co-ordinating Unit

Basin Coordinator: Dr. A. K. Sikka

Members: Dr. Abdul Haris A. and Dr. Adlul Islam

Indo-Gangetic Basin Coordination Unit at ICAR-RCER, Patna was established in November 2002, and is involved in coordinating CPWF Projects, their monitoring, stakeholder and researcher liaison in IGB countries India, Pakistan, Nepal and Bangladesh.

The main objectives of CPWF-IGB Unit are as follows:

- Establish a stakeholder group within IGB that will help to prioritize the research agenda for IGB.
- Initiate and coordinate a program of monitoring and analysis in IGB.
- Provide substantive management of the portfolio of projects in IGB.
- Make available to the parties all their collective and individual experience and expertise in improving the productivity of water in agriculture.

1. Coordination activities: The following coordination activities were undertaken:

- ➢ Regularly communicated with CP Secretariat on various technical and administrative issues, work plan and budget finalized for 2006 and letter of agreement signed.
- ➢ Institutional Linkages and working relations for better coordination with NARES, International Agencies located in the IGB and leading NGOs continued.
- ➢ Participated in the ICAR-IWMI Steering Committee Meeting as a Member of ICAR Delegation and as CPWF Basin Coordinator of IG-Basin.
- ➢ CPWF International Forum on Water and Food and CPWF second call for concept notes were forwarded and circulated to all the IGB Stakeholders.
- ➢ Basin coordinator's Assessments reports for all six projects in which IGB is a major basin and SG-507, SG-508 and SG-512 were prepared and submitted to CPWF Secretariat.
- ➢ Co-ordinated with TVEAP Team for Video Filming of the project PN-7 at Lucknow from 24th - 27th September 2006.
- ➢ Exchange of views through emails and personnel contacts with Stakeholders in IGB and maintained linkages, stakeholder and researcher liaison.
- ➢ Prepared and submitted workplan & budget 2007 for the CPWF-IGB unit based on the discussion made during the meetings with the Theme Leaders, Basin Coordinators and Management Team at Montpellier, France during the period 23rd - 27th October 2006. Dr. Abdul Haris attended the meeting.

- Success stories on "Strengthening of Stakeholders partnership in enhancing water productivity" and "Unleashing the potential of Water Productivity assessment and enhancement including multiple use of water" were prepared and sent to CPWF**.**

2. Core research activities:

- Final version of IGB-Basin Profile corrected and submitted for publication.
- Attended Asia Project Leaders meeting organized by CPWF at Vientiane, Loas from February 13-17th 2006.
- Participated and provided feed back to proponents of Expression of Interest for BFP proposal submission.
- Participated in the River Linking Session focused at PN48 during the IWMI-TATA Annual Partners meet, 8-10th March 2006.
- Attended CPWF project workshop on "Legal, Policy and Institutional Framework for Integrated Water & Forests Management" at PSI, Dehradun, during 4-7th April 2006.
- Attended Second Annual Review and Planning Meeting, PN-7, 25-27th April 2006, Karnal.
- Attended inception workshop of PN-48, 2-3rd May 2006, New Delhi
- Provided recommendations and feedback to PI's of CPWF projects as part of monitoring and evaluation.
- Organized and attended the "Impact Pathways Workshop" and "Annual Stakeholders Workshop-2005" at Kathmandu, Nepal during 30th June - 2nd July and 3rd - 4th July, 2006 respectively.
- Participated as the Basin Coordinator in the workshop "Improved Fisheries Productivity and Management in Tropical Reservoirs" on 26th December 2006 at New Delhi..

3. Basin specific research activities:

- "**CPWF Annual Stakeholders Workshop for Indo-Gangetic Basin**" on **3rd - 4th July 2006** was jointly organized by CGIAR Challenge Program on Water and Food, Indo Gangetic Basin Coordination Unit, Patna and International Water Management Institute (IWMI), Nepal at Hotel Himalaya, Lalitpur, Kathmandu, Nepal.

  The workshop aimed at strengthening the stakeholder participation in CPWF activities in Indo-Gangetic Basin, synthesis of water related activities of CP & non-CP funded projects, data base management, developing a network of partners in a regional alliance mode and dissemination and scaling up of CPWF projects outputs in IG Basin. Forty participants attended the workshop from Bangladesh (1), India (11), Nepal (20), Pakistan (1), IWMI, Colombo (3), IRRI, Philippines (2), World Fish Centre (1) and CPWF, Colombo (1). Participants came from a cross-section of institutions: government departments, research institutions, universities and NGOs.

- Organized a workshop on " **Drought, Risk and Management for Agricultural Water Use**" from **20th - 26th August 2006** as one of the CA-CPWF Session organized by CGIAR Challenge Program on Water and Food during World Water Week at Stockholm.

  Conclusions of the workshop included the following :

  - Risk and uncertainity in agricultural water management are related to both rainfed and irrigated agriculture. While in rainfed agriculture, reductions in rainfall, such as drought, and changes in the timing and frequency of precipitation are important, irrigated agriculture can contribute to risks in the area of food safety and irrigation structures themselves can increase the risk of water availability for other users and uses and can thus magnify droughts and flow variability, particularly at the basin level.
  - There are many types of modeling tools that can assist decision makers to address risk and uncertainty in agricultural water management. Hydrological models deal with the supply side, optimization models with allocation, and crop water requirement and demand forecast models focus on the water demand side. Discussants agree that advances in modeling tools enhance the possibility to manage water-related risks in agriculture, and thus improve risk resilience.
  - There are many instruments that can be applied to mitigate risks. They include payments for environmental services, warehouse receipts, and weather insurance. However, their successful implementation requires transparency, profitability for all parties involved, and suitable institutions to manage these instruments.

- Participated and presented the paper entitled ***"Crop and agricultural water productivity assessment in the tubewell and canal command of Bihar in India"*** *by A. K. Sikka, A. Upadhyaya, A. Abdul Haris, A. Reddy and A. Dey* in the water productivity session during the International Forum on Water and Food on "*Synthesizing knowledge on livelihoods, water, food and the environment*" at Vientiane, Lao PDR, during 12 - 17 November 2006.